

## CLAIMS

1. A method of placing pilot symbols in a data stream for telecommunication systems, wherein the pilot symbols are spaced in time using a range of different intervals between symbols.
- 5 2. A method in accordance with claim 1, wherein the distribution of pilot symbols in time is substantially fractal in nature.
3. A method in accordance with claim 2, wherein the distribution of pilot symbols involves repetitions of irregular groupings of pilot symbols in the data stream.
- 10 4. A method in accordance with claim 3, wherein said irregular groupings of pilot symbols are irregularly spaced in the data stream.
5. The method of any preceding claim, the data stream comprising a data packet, wherein the pilot symbols are placed with irregular spacing within a first level group (L0 level), the irregular spacing is repeated in a plurality of such L0 groups, and the  
15 L0 groups are placed with irregular spacing within a second level group (L1 level).
6. The method of claim 5, wherein the irregular spacing between the L0 groups is repeated in a plurality of L1 groups across the data packet, and the L1 groups are placed with irregular spacing within a third level group (L2 level).
7. The method of claim 6, wherein each L0 groups has length A, each L1 group  
20 each has length B, and the L2 group has length C, the pilot symbol distribution selected such that the ratio A:B is approximately equal to the ratio B:C.
8. The method of any preceding claim, wherein the pilot symbols extend across substantially the entirety of the data packet.
9. A method in accordance with any preceding claim, wherein the spacing of the  
25 pilot symbols is decided in accordance with a mathematical relationship, such that their positions are substantially predictable, but sufficiently unevenly spaced to improve the ratio of the pilot symbol spectrum corresponding to the most likely

frequency to that of the next most likely frequency, when compared with that available from an equivalent data stream containing evenly spaced pilot symbols.

10. A signal processing device for use in a communications system for generating a data stream for telecommunication systems, the signal processing device  
5 configured to implement the method of any preceding claim.

11. A receiver method for receiving and acquiring a transmitted signal in a communications system, the signal representing a data stream including data symbols and pilot symbols, the method including the steps of:

receiving the transmitted signal and converting to a digital signal;

10 iteratively acquiring the frequency of the signal by the following steps:

based on an assumed zero phase difference between certain relatively closely spaced pilot symbols within the data stream, calculating a first estimate of phase and signal amplitude;

15 calculating a relatively fine frequency estimate with potential aliasing ambiguity, based on more widely spaced pilot symbols within the data stream;

using said relatively fine frequency estimate to calculate a phase difference between said relatively closely spaced pilot symbols, and calculating a relatively coarse frequency estimate based on this phase difference, with no aliasing ambiguity;

20 using the calculated relatively coarse frequency estimate to enhance the relatively fine frequency estimate by refining said calculated phase and signal amplitude, and thus re-calculating said relatively fine frequency estimate;

25 using said relatively coarse frequency estimate and the enhanced relatively fine frequency estimate to resolve potential aliasing ambiguity in the relatively fine frequency estimate; and

applying the enhanced relatively fine frequency estimate to the data stream in the acquisition of the data symbols.

12. A receiver method for receiving and acquiring a transmitted signal in a communications system, the signal representing a data stream including data symbols and pilot symbols, the method including the steps of:

receiving the transmitted signal and converting to a digital signal;

5 acquiring the frequency of the signal by the following steps:

- a) a medium frequency estimation step;
- b) a coarse frequency estimation step based on the result of step (a);
- c) a medium frequency re-estimation step based on the result of step (b);
- d) an adjustment to the medium frequency estimation to resolve potential  
10 aliasing ambiguities in the medium frequency estimation;
- e) a fine frequency estimation step, including a calculation of a likelihood for the selected frequency;
- f) an adjustment to the fine frequency estimation to resolve potential aliasing ambiguities in the fine frequency estimation.

15 13. The receiver method of claim 12, including the further step of:

- g) a phase and signal estimation and correction step based on the result of step (f).

14. The receiver method of claim 13, including the further step of:

- h) the removal of the pilot symbol from the data stream to provide a data  
20 symbol output.

15. The receiver method of claim 13, including the further step of variance estimation.

16. The receiver method of any one of claims 11 to 15, including a process for further improving the reliability of acquisition by using additional encoded pilot  
25 symbols embedded within the data stream, the additional pilot symbols encoded

with forward error correcting codes; the process including the steps in the receiver of:

i) acquiring a list of the most probable time and frequency offset pairs ranked in order of probability;

5 ii) for each said time and frequency offset pair in the list, starting with that with the highest probability, and proceeding in order of decreasing probability:

decoding the packet on the basis of that time and frequency offset;

if a predetermined number of said additional encoded pilot symbols match their prescribed values, accepting that time and frequency offset;

10 if not, continuing to the next time and frequency offset pair in the list.

17. The receiver method of any one of claims 11 to 16, applied to a transmitted signal produced by the method of any one of claims 1 to 10.

18. The receiver method of claim 17, enhanced for greater data transmission efficiency, wherein in the data stream selected one or more of the pilot symbols are  
15 replaced with data symbols, and the acquisition steps are applied based on the assumption that these selected symbols are pilot symbols with zero value.

19. A receiver for receiving and acquiring transmitted signals in a communications system, the signals representing a data stream including data symbols and pilot symbols, the receiver including:

20 a functional block for receiving the transmitted signal and converting to a digital signal;

a functional block for iteratively acquiring the frequency of the signal, comprising :

25 a functional block for, based on an assumed zero phase difference between certain relatively closely spaced pilot symbols within the data stream, calculating a first estimate of phase and signal amplitude;

a functional block for calculating a relatively fine frequency estimate with potential aliasing ambiguity, based on more widely spaced pilot symbols within the data stream;

5 a functional block for using said relatively fine frequency estimate to calculate a phase difference between said relatively closely spaced pilot symbols, and calculating a relatively coarse frequency estimate based on this phase difference, with no aliasing ambiguity;

10 a functional block for using the calculated relatively coarse frequency estimate to enhance the relatively fine frequency estimate by refining said calculated phase and signal amplitude, and thus re-calculating said relatively fine frequency estimate;

a functional block for using said relatively coarse frequency estimate and the enhanced relatively fine frequency estimate to resolve potential aliasing ambiguity in the relatively fine frequency estimate; and

15 a functional block for applying the enhanced relatively fine frequency estimate to the data stream in the acquisition of the data symbols.

20. A receiver for receiving and acquiring transmitted signals in a communications system, the signals representing a data stream including data symbols and pilot symbols, the receiver including:

20 a functional block for receiving the transmitted signal and converting to a digital signal;

a functional block for acquiring the frequency of the signal, including:

a) a functional block for carrying out a medium frequency estimation step;

25 b) a functional block for carrying out a coarse frequency estimation step based on the result of step (a);

c) a functional block for carrying out a medium frequency re-estimation step based on the result of step (b);

d) a functional block for carrying out an adjustment to the medium frequency estimation to resolve potential aliasing ambiguities in the medium frequency estimation;

e) a functional block for carrying out a fine frequency estimation step, including a calculation of a likelihood for the selected frequency;

f) a functional block for carrying out an adjustment to the fine frequency estimation to resolve potential aliasing ambiguities in the fine frequency estimation.